The Effect of Plastic Waste and Fly Ash Substitution on The Bending Strength of Concrete

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Abstract. Concrete mixes have changed significantly over time due to advances in science and technology, including the addition of new ingredients and the replacement of some existing ones. Plastic and fly ash waste which has not been used properly can now be utilized. Due to their negative impact on the environment, these two materials are used. The American Concrete Institute (ACI) 112.4R 1993 method was used for concrete mix planning, with changes in the addition of 1.5% HDPE plastic waste pieces and fly ash with variations of 0%, 5%, 10%, 15%, 20%, and 25%. Based on the results of the concrete flexural strength test, the addition of 1.5% HDPE plastic waste and 5% fly ash gave the best results, namely an increase of 5.300% for concrete aged 28 days and 5.303% for concrete aged 56 days.

Keywords: HDPE plastic waste, fly ash, flexural strength.

1 Introduction

Concrete is typically made up of cement, coarse aggregate, fine aggregate, filler, and water. However, as science and technology advance, concrete mixtures endure various adjustments, such as being given extra elements or substituting a substance in concrete to satisfy specific needs [1].

In producing concrete quality that meets standards, innovation and technology are needed to create superior and quality products. One of the latest innovations is the use of plastic waste and fly ash as additional materials in concrete production.

HDPE (Hight Density Polyethylene) plastic waste is a material that is often found in everyday life and its use always increases along with the increase in human population, causing an increase in plastic waste around us. Plastic waste is also a material that is difficult to decompose in the soil and takes hundreds of years to decompose. HDPE plastic waste is one type of high-density polymer that is flexible, impact resistant and resistant to low temperatures [2].

Fly ash is obtained from the remaining results of the coal combustion process which is removed from the combustion furnace. Waste from fly ash always increases every year, so it needs to be countermeasured. Fly ash waste can cause quite harmful environmental impacts, especially air pollution to surrounding life. Therefore, efforts are needed for fly ash to become a useful

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material, including for concrete mixing [3]. The use of fly ash in concrete can replace part of the cement so that the use can produce higher concrete compressive strength [4].
In this research we will try adding fly ash to plastic waste. Plastic waste here is used as the dependent variable with the percentage of plastic waste used in the concrete mixture being 1.5%, while the independent variable uses fly ash with variations of 0%, 5%, 10%, 15%, 20%, and 25% of the cement weight. From the research, it can be seen that the use of plastic waste and fly ash in the concrete mixture can increase the compressive strength and flexural strength of concrete. It is hoped that the use of plastic waste and fly ash can improve concrete performance. This research was carried out to obtain the optimum percentage value for use of fly ash in the concrete mixture which was added with 1.5% plastic waste to produce maximum flexural strength. This study also aims to obtain the optimum value of the optimum use of fly ash in the concrete mix which is added with 1.5% chopped plastic waste.

2 Research Methods

In this study there are steps that will be carried out as follows:

2.1 Material Testing

Concrete results are greatly influenced by the quality of the material. The more it meets the standards, the higher the quality of the concrete produced. Material testing is needed to obtain high quality materials. The material testing standards used in this research are based on the Indonesian National Standards (SNI). Material testing is only carried out on coarse aggregate, medium aggregate, fine aggregate and plastic waste. No testing is carried out on cement because the cement produced has been tested in the laboratory according to predetermined requirements, so its quality is guaranteed.

2.2 Concrete Mix Making

The manufacture of this concrete mixture is based on the planning of the concrete mixture that has been made. The concrete mixture material that has been obtained during planning is then weighed according to its composition. All materials are mixed with the help of concrete mixer. Do the initial mixture, which consists of cement, sand and gravel. When mixing water, there is a little special treatment in the admixture, namely cyclic concrete. Sikacim concrete must first be mixed with mortar water approximately 2.384% of the amount of mortar water used. Sikacim concrete that has been mixed with water is first put in the initial mixture and then can be added other remaining mortar water if still needed.

2.3 Mix Design

The standard used in concrete mix planning in this study refers to ACI 211.4R-93 [5]. To gather the data required when planning concrete mixtures, all components to be used must be tested. The mixture planning results in a composition for each element required in the concrete mixture, which includes water, cement, fine aggregate, coarse aggregate, plastic HPDE, and fly ash.

2.4 Test Slump

The implementation of the slump test aims to determine the level of softness or plasticity of concrete mortar, so that the value of the concrete viscosity can be known. This concrete mixture requires water and its needs according to planning and calculation. According to SNI SNI 03-1972-1990 1990 slump testing is carried out with a standard decapitated cone with a peak diameter of 10 cm. The diameter of the base is 20 cm and the height is 30 cm, and also uses a compactor stick with a diameter of 1.6 cm and a length of 60 cm. Slump used for compaction method which is divided into 3 layers by piercing 25 times for each layer.

2.5 Test Specimen Manufacturing

The process of making test specimens is basically carried out after the material mixing process has been carried out. The mold used in making test specimens is a cylinder with a size of ø15 x 30 cm for compressive tests and a beam measuring 15x15x60 cm for flexure tests, where before the concrete mixture is inserted, the mold must first be greased using lubricating oil. Applying oil to the mold aims to make it easier when removing the concrete mold [7].

2.6 Test Specimen Care

Curing is a way to treat concrete using water. In the treatment process, the specimen is immersed in water for a predetermined time, usually the concrete is immersed until the concrete compressive strength test life at the age of 28 days or 56 days.

Based on 2493:2011 standard treatment consists of 2 parts, initial treatment and final treatment. Initial maintenance is carried out by storing test specimens for a maximum of 24 hours immediately after printing and finishing in the temperature range of 16-27 °C.

2.7 Flexural Strength Testing

Concrete bending strength is the ability of concrete blocks arranged in two locations to endure forces directed perpendicular to the axis of the test specimen until it breaks, expressed in Mega Pascals (MPa) force per unit area. When a load is applied to a beam, it deforms, and bending moments develop as a result of the material that makes up the beam's resistance to external loads. The tension generated during deformation must not exceed the concrete material's bending stress limit. To analyze the bending strength of concrete there are two ways, namely: (a). if the fracture plane is located in the central area (area 1/3 the distance of the resting point of the tengak is calculated by equations (1) and (b). if the fracture plane is outside the center (area 1/3 distance of the central laying point) and the distance between the center point and the breaking point is less than 5% then it is calculated by equation (2).

$$fr = \frac{PL}{bh^2} \quad (1) \qquad fr = \frac{Pa}{bh^2} \quad (2)$$

fr is the bending strength (Mpa), *P* is the load at the bending time (N), *L* is the distance between pedestals (mm), *a* is the distance from laying to force (mm), *b* is the beam cross-sectional width (mm), *h* is the beam cross-sectional height (mm).

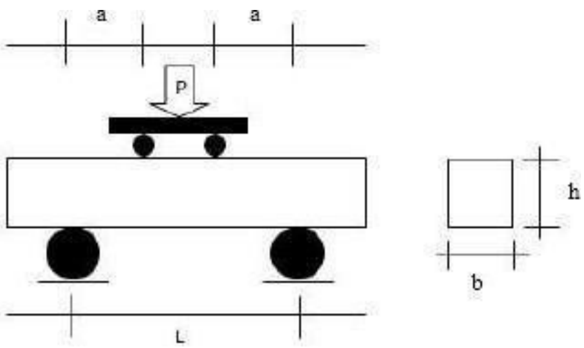

Figure 1 Flexural Strength Testing

3. Result and Discussion

3.1 Design of a Concrete Mix

The concrete mixture is designed in accordance with the standard guidelines established by ACI 211.4R-93. **Table 1** shows the material data required to build a concrete mixture. From this data, the amount of material required per m3 for the ages of 28 days and 56 days may be calculated from this material data can be known the amount of material needs per m3 for the age of 28 days and 56 days which can be seen in **Table 2** and **Table 3.**

Table 1 Material data for concrete mix design

Material Physical	Data Unit	Fine Aggregate	Medium	Coarse Aggregate
Solid Fill Weight (DRUW)	Kg/lt	1,57	1,63	1,70
BJ SSD		2,57	2,67	2,63
BJ Kering		2,49	2,62	2,60
Absorption	%	3,38	1,92	1,13
Water Content	%	2,62	1,41	2,02
Composition	%	47	38	15
Dropsy Factor		1,18	1,15	1,15

Table 2 Number of Needs per 1 m3 age 28 days

Material Type	Unit Variation	Variation 0% without ZA	Variation 0% + ZA	Variation 5% + ZA	Variation 10% + ZA	Variation 15% + ZA	Variation 20% + ZA	Variation 25% + ZA
Cement	kg/m³	419,86	487,53	463,16	438,78	414,40	390,03	365,65
Fly ash	kg/m³	0	0	24,38	48,75	73,13	97,51	121,88
Fine Aggregate	kg/m³	504,53	481,77	474,68	467,60	460,51	453,42	446,34

Material Type	Unit Variation	Variation 0% without ZA	Variation 0% + ZA	Variation 5% + ZA	Variation 10% + ZA	Variation 15% + ZA	Variation 20% + ZA	Variation 25% + ZA
Medium Aggregate	kg/m³	904,50	904,50	904,50	904,50	904,50	904,50	904,50
Coarse Aggregate	kg/m³	314,51	314,51	314,51	314,51	314,51	314,51	314,51
Sikacim Concrete	kg/m³	0	11,62	11,04	10,46	9,88	9,30	8,72
Water	kg/m³	190,17	169,48	170,01	170,53	171,06	171,59	172,12
Plastic Waste	kg/m³	0	0	2,92	2,91	2,90	2,88	2,87

Table 3 Number of Needs per 1 m3 age 56 days

	Unit Variation	Variation 0% without ZA	Variation 0% + ZA	Variation 5% + ZA	ZA	Variation 15% + ZA	Variation 20% + ZA	Variation 25% + ZA
Cement	kg/m³	361,38	461,92	438,82	415,73	392,63	369,54	346,44
Fly ash	kg/m³	0	0	23,10	46,19	69,29	92,38	115,48
Fine Aggregate	kg/m³	504,53	503,83	497,11	490,40	483,68	476,97	470,25
Medium Aggregate	kg/m³	904,50	904,50	904,50	904,50	904,50	904,50	904,50
Coarse Aggregate	kg/m³	314,51	314,51	314,51	314,51	314,51	314,51	314,51
Sikacim Concrete	kg/m³	0	11,01	10,46	9,91	9,36	8,81	8,26
Water	kg/m³	182,31	162,03	170,75	171,25	171,75	172,25	172,76
Plastic Waste	kg/m³	0	0	2,96	2,95	2,94	2,93	2,91

3.2 Testing When Mixing Concrete

Tests carried out at the time of mixing are testing concrete slump and concrete fill weight. In this study, the slump value obtained by each variation varied, but the slump value obtained had met the plan limit, namely 1-2inch without the addition of addictive substances and 2-4 inches with the addition of addictive substancesFurthermore, from the results of the concrete density of the test specimens in Figure 2, it is known that the density values of the solid and mechanical concrete in each variation have met the standards and the mixture can be used for concrete test specimens. According to SNI 3402:2008 the weight of concrete contents ranges from 2.5 – 3.3 kg/lt. The weight of concrete contents is affected by two factors: the weight of the material contents and the density of the concrete mixture [8]. When each concrete variation sample has the same material, the variance in the weight value of the concrete content is due to the density of the mixture. The weight of the concrete content increases with the density of the mixture. As the amount of fly ash in the concrete mixture grows, so does the weight of the concrete.

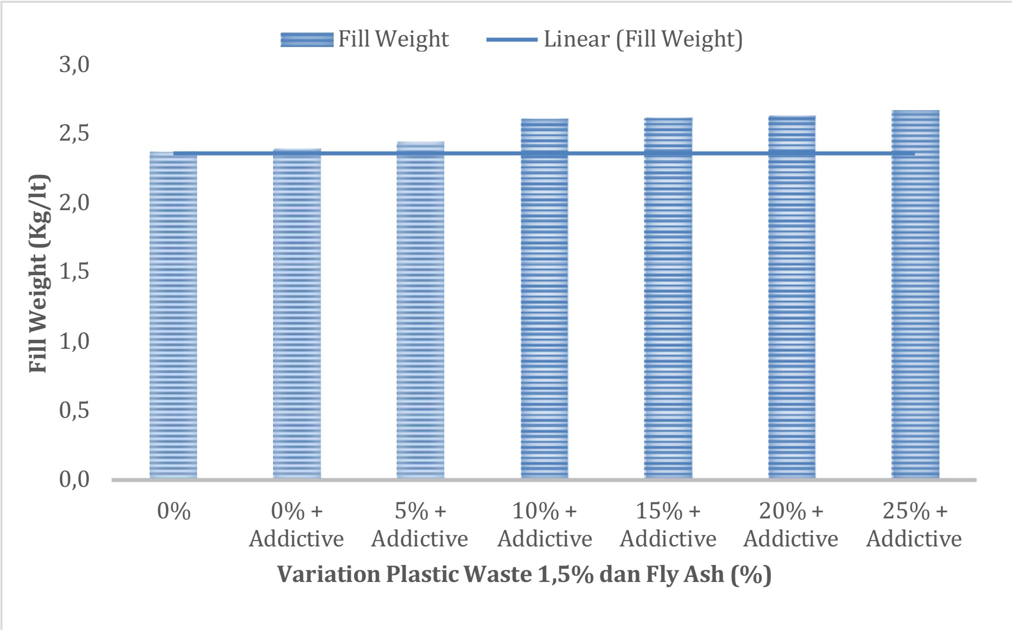

Figure 2 Manual Solid Fill Weights

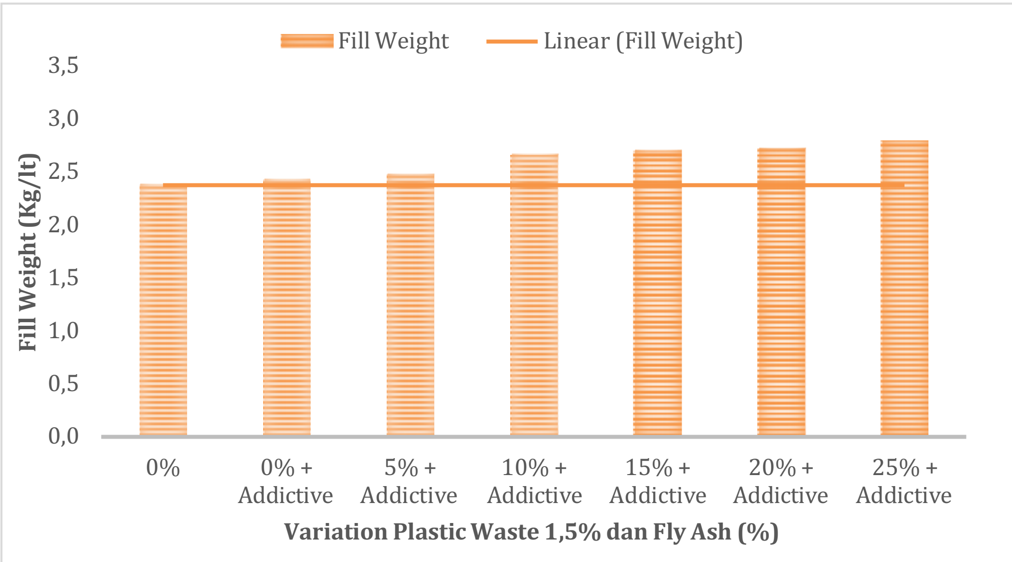

Figure 3 Mechanical Solid Fill Weights

3.3 Flexural Strength Concrete Testing

The graphs in **Figures 4** and **Figures 5** show the results of measuring the flexural strength of concrete with the addition of shredded plastic waste at 28 days and 56 days.

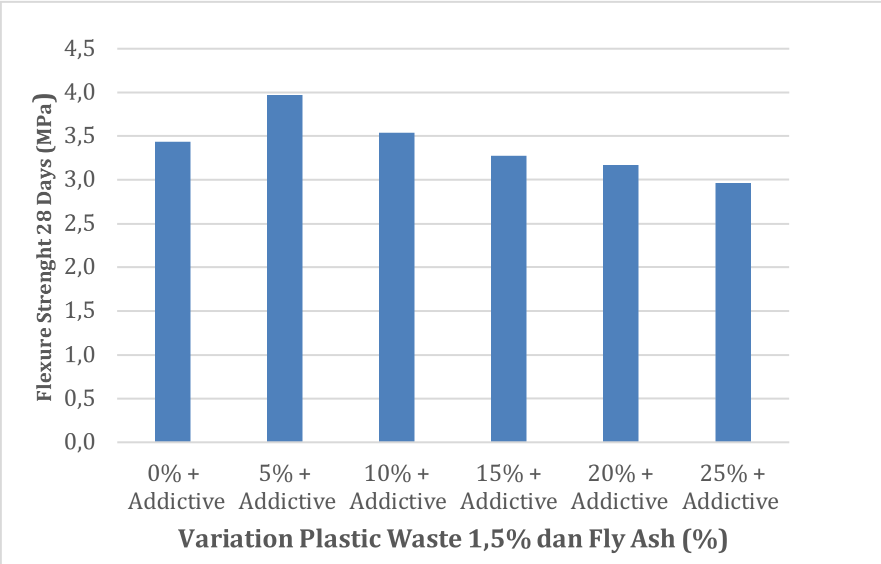

Figure 4 Graph of 28 Days Life Flexural Strength Test Results

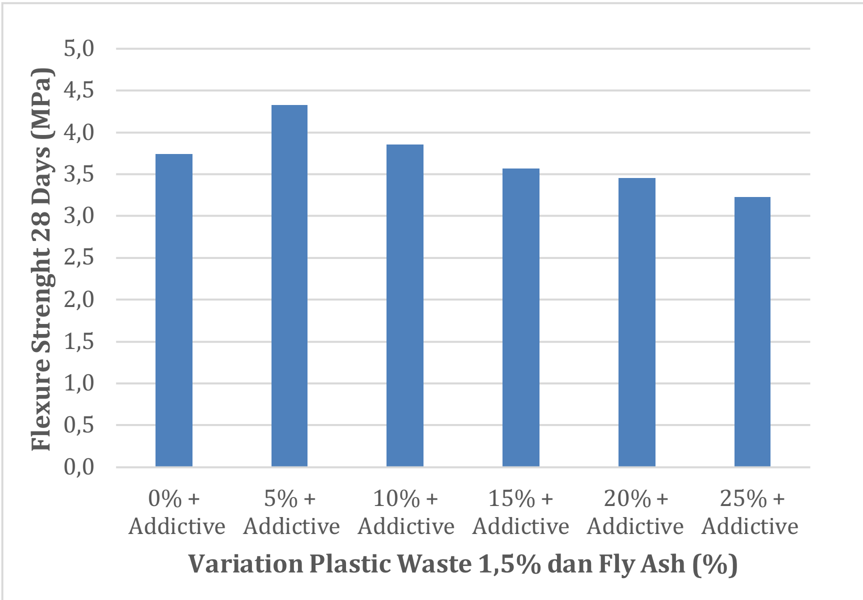

Figure 5 Graph of 56 Days Life Flexural Strength Test Results

Based on the graphs in Figure 4 and Figure 5 of the test data on the flexural strength of concrete aged 28 days and 56 days, it can be seen that the flexural strength of concrete has increased in the variation of plastic waste by 1.5% and fly ash by 5% (3,971 MPa) by 5,300% of concrete variation of 0% (3,771 Mpa) at the age of 28 and 5.303% at the age of 56 days. Based on Pd T-14-2003 (Cement Concrete Road Pavement Planning of the Department of Settlement and Regional Infrastructure) explains that concrete is included in the category for the use of rigid pavement, namely concrete that has concrete bending strength ranging from 3 - 5 MPa. In the results of concrete bending strength at the age of 28 days in Figure 4 obtained the maximum value of concrete bending strength of 3.971 MPa and the results of concrete bending strength at the age of 56 days in Figure 5 obtained the maximum value of concrete bending strength of 4.329 MPa and has met the established standards.

4. Conclusion

The optimum occurred in the concrete mixture of beam specimens, namely with the addition of 5% fly ash, with a percentage increase in the maximum flexural strength value of 5.301% for aged flexural strength when testing the flexural strength of test specimens with the percentage addition of 1.5% HDPE plastic waste and fly ash. Flexural strength at 56 days was 5.303% higher than at 28 days.

Based on Pd T-14-2003 (Cement Concrete Road Pavement Planning, Department of Settlements and Regional Infrastructure), it explains that concrete is included in the category for the use of rigid pavement, namely concrete that has a flexural strength of concrete ranging from 3 - 5 MPa. It is hoped that future studies will use chopped plastic waste of different sizes, such as plastic waste that passes a 9.5 mm filter and is retained by 4.75 mm and so on.

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